

Cleome viscosa Linn: A natural source of pharmaceuticals and pesticides

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Cleome viscosa is an indigenous medicinal plant that shows large seasonal biodiversity in North-Western states of India. It is a common weed mainly found in crop fields, in waste lands, wet and grassy places all over the plains of India. Plant bears yellow flowers and long slender pods containing seeds that resemble those of mustard with strong penetrating odor in rainy and post rainy season. Seeds are oil producing and are used for making cattle cake. *C. viscosa* leaves and young shoots are used to cook like a vegetable, which is having sharp mustard-like flavor. Fatty oils of the seeds of *C. viscosa* contain major fatty acids, as methyl esters, of the oils mainly palmitic acid (10.2–13.4%), stearic acid (7.2–10.2%), oleic acid (16.9–27.1%) and linoleic acid (47.0–61.1%). Oil is rich in unsaturated fatty acids and nutrients, especially Vitamins A and C, minerals, calcium, iron and protein. Plant also contains free gallic acid, gallotannins, iridoid, saponins and terpenoid polyphenolic compounds, which are well-known antioxidizing agents. Its oil is very similar in fatty acid composition to the nonedible oils of rubber, jatropha, soybean, safflower, linseed and rapeseed edible oils. Due to the presence of oils, plant can be used as a good source of green biodiesel. In the present review article, both pharmaceuticals and insecticidal properties of *C. viscosa* have been described in detail with special emphasis on its commercial use for production of non edible oil that can be used as biodiesel. Plant grows in tropical and subtropical climatic conditions.

Key words: *Cleome viscosa*, folk medicine, nutraceuticals, pharmaceuticals, secondary metabolites

INTRODUCTION

Cleome viscosa belongs to family *Cleomaceae*. It is a small family of flowering plants in the order brassicales having approximately 300 species belong to 9 genera. The genus *Cleome* is well recognized and shows subcosmopolitan distribution throughout the tropical and warm temperate regions of the world. It contains about 180–200 species of ethnomedicinal, ethnobotanical and ecological importance. It contains 170 families among which herbaceous annual or perennial plants and shrubs are represented in different regions. *C. Viscosa* Linn is a widely distributed terrestrial, annual, sticky herb that attains a height, up to 120 cm. It is a fodder plant commonly known as hur hur in Hindi. Plant is characterized by its yellow flowers and long slender pods containing seeds. Seeds are similar to mustard with strong penetrating odor.^[1] *C. viscosa* L. is small size herb with yellow flowers and long slender pods containing seeds [Figure 1]. Leaf and stem surfaces of *C. viscosa* L. shows presence of secretory glandular trichomes with

club cylinder and cylinder morphologies.^[2] *C. viscosa* plant is erect, grooved, aromatic glandular and contains sticky shoots. Stem is rounded, solid, (glandular) hairy while root is taproot branched white or brown. Plant bears, elliptic-oblong, obovate leaflets of variable in size (1.5–2.5 cm) broad and petiole up to 5 cm long.

Leaves are sessile, compound, trifoliolate, alternate, spiral, stalked, foliate in shape and contain glandular hairs on both sides, leaflets are elliptic, (glandular) hairy on both side, margin entire, apex acute, base acute, pinnately veined. Flowers are pedicelate, bisexual, single, axillary, stalked, yellow, petals 4 and free. These are white or yellow in color. Flowering occurs from May to September and fruiting in August to November. Inflorescence is racemose or corymbose. Stipules are absent. Pedicels are 6–20 mm long; bracts foliaceous, petals 8–15 mm long, 2–4 mm broad, oblong-obovate. Stamens are 10–12 and rarely occur up to 20 and not exceeding the petals; gynophores absent. Sepals are oblong-lanceolate, 3–4 mm long, 1–2 mm wide, glandular-pubescent. Fruits are dark brown 30–75 mm long and 3–5 mm broad in size, a capsule, either a slender, linear-oblong capsule, erect, obliquely striated and tapering at both ends. Its two valves contain hundreds of seeds that are oil producing.^[3] The whole plant is sticky in nature and has a strong odor resembling asafoetida. Plant has great ethnomedicinal value and is extensively used by local tribes of India for various therapeutic purposes. Local people of Rajasthan, Haryana, Uttar Pradesh and Delhi Aravali area extract

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Figure 1: *Cleome viscosa* plant with yellow flowers and long slender pods

seed oil. Plant is also used for treatment of various diseases by natives and traditional healers of India.^[4,5] *Cleome* and its associating species are used to treat various disorders such as diarrhea, fever, inflammation, liver diseases, bronchitis, skin diseases and malarial fever. The juice is useful in piles, lumbago, and earache.^[4]

DISTRIBUTION

Cleome viscosa is a weed distributed throughout the tropics of the world and the plains of India. *C. viscosa* is naturalized throughout the hot and moist parts of India. It is an annual wild duration plant species formed in Indo-Gangetic plains. It is a tolerant ruderal plant found on arable land, along roadsides, refuse heaps, coconut grooves, often in great quantities. It is found throughout the greater part of India, often in waste places. Plant prefers sunny, lighter soil, and found in both under seasonally dry and under ever-wet conditions. Sometimes it grows on sandy or calcareous soils. In Eastern Java plant grows on recently formed, highly porous and light volcanic soil. Plant also grows along and near the sea coast or in savannahs, up to 500 m altitude. Plant grows annually in the rainy season and found throughout the hot and moist climatic zones of India. This is a common weed mainly found in crop fields, in waste and grassy places all over the plains of India and Pakistan. *Cleome* diversity is also reported in Southeast Asia, Malesia, tropical Australia, and tropical Africa and Southern Arabia. *Cleome* represents C3 photosynthesis to C4 photosynthesis plants. Plant is identified by different names, in Hindi it is named as Hurhur or Bagra, Hurhuria in Bengali, Hul hul in Urdu, Pilitalvani in Gujrati, Naikkaduku in Tamil, Naivela in Malayalam, Kukkavaminta in Telugu, Pivala tilavan in Marathi, and as wild or dog mustard in English.

THERAPEUTIC USES

The natives and traditional healers of India,^[4,5] use *C. viscosa* Linn. for various therapeutic purposes. In traditional system of medicine, this plant is used to treat various disorders such as diarrhea, fever, inflammation, liver diseases, bronchitis, skin diseases and malarial fever. The juice is useful in piles, lumbago, and earache.^[4] The leaves are

diaphoretic, rubefacient and vesicant and are used as an external application to wounds and ulcers. The juice of the leaves has been used to relieve earache. Whole plant and its various parts that is, leaves, seeds, and roots are widely used in traditional and folkloric systems of medicine for the treatment of various ailments by the local people of Rajasthan, Haryana, Uttar Pradesh and Bihar, Karnataka and Maharashtra. Fresh leaves of *C. viscosa* are used as vegetable. Leaf decoction is used in the treatment of respiratory tract infections, wounds and jaundice. Leaf juice is also used to relieve earache and eyesore. The leaves are diaphoretic, rubefacient and vesicant used as an external application to wounds and ulcers. The sap of leaves mixed with water or milk is applied to the eye in Java. Both leaf and seed oil is used for various veterinary and medicinal purposes while whole plant is used to cure rheumatism. The seeds of *C. viscosa* are used in traditional systems of medicine for the treatment of many diseases in Asia. *Cleome* seeds are used in curries and are also added to tobacco to enhance narcotic quality. The seeds contain 18.3% oil, a mixture of amino acids, fatty acids, and sucrose.^[6] Linoleic, palmitic, stearic, oleic and linolinic acids are present in the oil.^[7-9] The seeds contain an appreciable quantity of alkaloids, 0.1% viscousic acid and 0.04% viscosin. The oil is very similar in fatty acid composition to the nonedible oils of rubber, jatropha, and pongamia, soybean, safflower, linseed and rapeseed edible oils. Oil shows richness of unsaturated fatty acids.^[10] The *C. viscosa* biodiesel head the properties of standard biodiesel specified by American Society for Testing and Materials (ASTM) and Indian Standards Bureau except it had low oxidation stability.^[10] The whole herb is rubbed on the body against rheumatism. The seeds contain an appreciable quantity of alkaloids. Plant possesses diverse biological activities, antibacterial, antifungal, insecticidal and nematocidal.^[2] Its extracts were found active against *Bacillus subtilis*, *Pseudomonas fluorescens*, *Cyclus formicarius elyangulus* (summer, coleopteran, curculionidae), and parasitic nematode *Meloidogyne incognita*.^[2] *C. viscosa* L. is used traditionally in the Indian system of medicine as a carminative, anthelmintic and diuretic and are used for wound healing, ulcers, and diarrhea.^[11] Fresh leaves of this plant are used very effectively for the treatment of jaundice in the folk medicines in India [Table 1]. In addition, *C. viscosa* possesses significant gastroprotective activity due to free radical scavenging activity and addresses the folklore claim.^[11] Plant also shows hepatoprotective^[12] and antidiarrheal effect.^[13] Preliminary phytochemical screening of various solvent extracts shows diverse activity.

ETHNOMEDICINAL USES

The leaves, seeds and roots of the plant are widely used in traditional and folklore systems of medicine. Various plant parts show beneficial curative effects as anthelmintic,

Table 1: Biological activity of chemical constituents isolated from *Cleome viscosa* and its associating species

Plant parts used	Compounds isolated	Biological activity
Roots	Kaempferide 3-glucuronide	Antimicrobial, toxic
	[2-amino-9-(4-oxoazetidin-2-yl)-nonanoic acid]	Cytotoxic
Leaves	Querection 3-O-(2"-acetyl)-glucoside	Cytotoxic
	Flavonoids, Alkaloids, phenols	Antioxidant, anticancer
	Aromatic amines and alkynes	Antiplasmodial, antibacterial
	Amino acids	Nutritive
	Carotenoids	Free radical scavenging capacity, nutritive
	Cardiac glycosides,	Treatment of congestive heart failure, Cardiac arrhythmia, contraction, Calcium-induced calcium release
	Cyanogenic glycosides	Antiparasitic, poisonous
	Saponins	Antifeedants, Plant defense
	Triterpenes (lupeol, epi-lupeol)	
	Cytotoxic	Antitumor
	Sugars	Nutritive
	Arginine, aspartic acid, lysine, tyrosine and histidine	Nutritive
	Cleogynol (20s, 24s)-epoxy-19,25-dihydroxydammarane-3-one hemiketal	Anti-cancer, antibacterial
	Tannins	Repellent and insecticidal
	Isothiocyanate-producing glucosides	Antiparasitic, poisonous
	Monoacylated and diacylated	
	Cyanidin 3-sophoroside-5-glucosides	Antiparasitic, poisonous
	Anthocyanins	Cancer chemopreventive
	Cabralealactone	Analgesic, anti-inflammatory and antiemetic
	Ursolic acid	Analgesic, antiemetic
	Trinortriterpenoiddilactone	Cytotoxic
	Triterpenoidcleocarpone dormane terpenes	Cytotoxic
	Triterpenoidcleocarpone dormane terpenes	Cytotoxic
	Isokaempferide,	Cytotoxic, anticancer
	5,7,4'-trihydroxy-3,3'-dimethoxyflavone	Anticancer
	Jaceosidin, penduletin	Anti-inflammatory
	Axillarin	Toxic
	Chryso-splenetin	Anticancer
5,3'-dihydroxy-3,6,7,4',5'-pentamethoxyflavone	Antimicrobial, insecticidal	
5,4'-dihydroxy-3,6,7,8,3'-pentamethoxyflavone	Antimicrobial, insecticidal	
5-hydroxy-3,6,7,3',4',5'-hexamethoxyflavone	Antimicrobial, insecticidal	
5,7,4'-trihydroxy-6,3',5'-trimethoxyflavone	Insecticidal	
Essential oil	Phytol, (+)-cedrol, noctacosane	Toxic and repellent
	Dammarane-type triterpenes	Antimicrobial
	Triterpene	Insecticidal
		Antimicrobial
Green seeds	Bicyclic diterpene cleomeolide	Antibacterial
	Naringenin glycoside (coumarino-lignoids)	Hepato-protective
	Eleomiscosin A and B	Antibacterial
	Nevirapine	Anti-proliferative
Dry seeds	Macrocyclic diterpene	Anti-tumor
	Cleomaldeic acid	Cytotoxic
Seed oils	Butane	Anti-parasitic, Fuel
	Fatty acids and phytosterols	Nutritive
	Oleic acid, linolic acid, palmitic acid	Nutritive
	Stearic acid, arachidic acid	Nutritive
	Cleomiscosins (A, B and C)	Hepato-protective
	stigmasta-5,24 (28)-diene-3β-O-α-L-rhamnoside	Anti-inflammatory
	Unsaturated cembrane acids, glutamic acid	Cytotoxic and anti-inflammatory
	Sesquiterpenes	Insecticidal and antimicrobial

Contd...

Table 1: Contd...

Plant parts used	Compounds isolated	Biological activity
	Cleomeprenols	Antimicrobial, anti-oxidant
	Anthroquinones	Antiplasmodial, anticancer
	Glycosides	Antimicrobial
	Flavanols	Anti-convulsant
	Cleomeolide	Anti-arthritis properties
	Flavonoids kaempferol-3-O-glucoside	Antimicrobial
	Rutin	Anti-inflammatory inhibits platelet aggregation, hemorrhoids, varicosis and microangiopathy
	Luteolin-7-O-glucoside. .	Antimicrobial
	Macrocyclic diterpene	Anti-oxidant Antimicrobial
	Glucocapparin	Anti-microbial
	Glucocleomin	Anti-microbial
Seed	Contains 26% oil its major constituents	
	Methyl esters	Nutritive
	Palmitic acid stearic acid	Nutritive
	Oleic acid	Nutritive
	Linoleic acid	Nutritive
	Palmitoleic acid	Nutritive
	Octadec-(11E)-enoic acid	Nutritive
	Arachidic acid, eicosa-(11Z) enoic acid	Nutritive
	Linolenic acid	Nutritive
	Heneicosanoic acid	Antimicrobial
	Behenic acid	Antimicrobial
	Lignoceric acid	Antiparasitic
	Pentacosanoic acid	Nutritive
	Hexacosanoic acid	Nutritive
	12-oxo-stearic acid	Nutritive
	Alkanes tetracosane	Insecticidal
	Pentacosane-nonacosane	Insecticidal
	Triocontane, hentriacontane and dotriacontance	

antiseptic, carminative, antiscorbutic, sudorific, febrifuge,^[14] cardiac stimulant, immunomodulatory, antipyretic, psychopharmacological, anti-diarrheal, anti-inflammatory, hepatoprotective, anticonvulsant^[15] and anti-diarrheal activity.^[16,17] Plant is also used for treatment of skin diseases,^[18] gulma (any tumor, lump or diverticulosis), asthila (prostate enlargement), krmiroga (worm infection), kandu (pruritus), and karnaroga (ear diseases) in Ayurvedic medicinal system. *Cleome droserifolia* plant is commonly used in the Egyptian folk medicine for treatment of many diseases. In Taiwan, *Cleome gynandra* is used to treat dysentery, gonorrhoea, malaria, rheumatoid arthritis. *C. droserifolia* is used in Egypt as a traditional medicine for the treatment of diabetes mellitus. A decoction or infusion of boiled leaves and/or roots is administered to facilitate childbirth in pregnant women. Plant leaves are used to treat stomach-ache, constipation, and conjunctivitis. Leaves are applied externally over the wounds to prevent the sepsis. Sap from leaves may be used as an analgesic, particularly for headaches, and for treatment of severe thread-worm infection. Sap from pounded young leaves is squeezed into ears, nostrils and eyes to treat epileptic seizures and ear ache. It also provides relief in chest pain.

The bruised leaves are rubefacient, vesicant, and are used to treat headache, neuralgia, rheumatism, arthritis and other localized pains. The plant juice diluted with water is given internally in small quantity in fever.^[4,19] Traditionally the leaves, bark, root and seeds of the plants of *Cleome* genus are used as stimulant, anti-scorbutic, anthelmintic, rubifacient, vesicant, carminative, stomachic, laxative, diuretic, anti-inflammatory, anti-tumor, antiseptic, anti-leprosy.^[20,21] The plant is good for malarial fevers and useful in blood diseases, uterine complaints. Plant is well known for its anti-diarrhoeal^[13] wound healing and anti-ulcers properties [Table 1].^[11] Traditionally, this plant is used in various disorders such as diarrhea, fever, inflammation, liver diseases, bronchitis, skin diseases and malarial fever. The juice is useful in piles, lumbago, and earache.^[22] The plant is used to cure malarial fevers, blood diseases, and uterine complaints. *Cleome rupicola* plant extract is applied as eye-drops.^[23] Its seeds are stimulant and carminative and are traditionally used in the Indian system of medicine as anthelmintic^[24] diuretic,^[6,7,25] antiseptic and hepatoprotective activity.^[26] Seed oil possesses mutagenic properties.^[27] The crude methanol extract of *C. viscosa* (MECV) showed significant analgesic activity^[28]

while its seed oil shows peripheral analgesic and antiemetic activities. Plant extracts are also used to kill insects and parasitic nematodes.^[2] *Cleome arabica* L. (*Capparidaceae*) a desert plant widely distributed in the North Africa is used in traditional medicine as a sedative for abdominal and rheumatic pains.^[29]

NUTRACEUTICAL USES

The plant leaves and young shoots are used as vegetable, which contain sharp mustard-like flavor. The pungent seeds and seed pods are used as a mustard substitute in curries.^[30] Its seed oil also possesses high nutritional values^[7] and defatted seeds are used to make cake.^[6,7] Plant contains high fiber and low-fat content and is used for making pickles.^[31] *C. gynandra* is a rich source of nutrients, especially Vitamins A and C, minerals (calcium and iron) and proteins.^[32] *Cleome dolichostyla* seed oil possess good iodine number, saponification number, Hehner value, Reichert–Meissl number and refractive index, hence its seed oil can be used as an edible oil for human.^[33] *C. gynandra* is used as leafy vegetables and can be cultivated to assist in food security.^[34] Plant serves as an important starvation plant for modern Hopi people. Similarly, *C. gynandra* is cultivated alongside other vegetable.^[35] In India, *Cleome serrulata* is largely used as vegetable after boiling in water.^[36] *Cleome speciosissima* is cultivated herb that serves as bee food as well as for flowers.^[37] *Cleome integrifolia* leaves boiled with green corn are used in food.^[38] In the Sahara region, fruit and leaves of *C. arabica* L. mixed with olive oil are used to make anti-inflammatory ointments.^[39] Similarly, *C. gynandra* is widely used by people of South Africa and Central Lowveld Savanna Region.^[40] *C. viscosa* leaves and roots contain dietary constituents that are of high nutritional value.^[41,42] Plant seeds contain important dietary amino acids, proteins, lipids, fatty acids such as oleic and linoleic acids.

Phytochemistry

More than 50 species of *Cleome* have been analyzed for their phytochemical investigations. These have shown wider chemotypic, genotypic and biological activities in diverse ecological climates. *C. viscosa* L. possesses a variety of phyto principles,^[14] which are well-known for its medicinal properties. Plant contains sugars and amino acids of high nutritive value.^[41] From leaves of *Cleome spinosa* L flavonoids,^[42,43] phenolics,^[44] and cleomeprenols (nonaprenol, decaprenol and undecaprenol) were isolated from.^[45] *Cleome* seeds contain various fatty acids,^[46] coumarinolignoids, cleomiscosin A and cleomiscosin B.^[47-52] Flowers of *C. viscosa* contain anti-inflammatory and anti-microbial flavone glycoside,^[53] while its seeds contain cleomiscosins coumarino-lignoids,^[54] cleomiscosin D a coumarinolignan.^[55] Cleosandrin a novel 7 phenoxy coumarin

is isolated from the seeds of *Cleome icosandra*.^[56] Similarly, an active nevirapine, a dipyrrodoiazepinone metabolite is also isolated from the seeds of *C. viscosa*.^[57] Plant also contains unsaturated cembrane acids,^[58] cembranoid diterpene, and triterpenes^[59] [Table 1 and Figure 2]. From *C. viscosa* roots contain few important compounds that is, kaempferide 3-glucuronide,^[60,61] naringenin glycoside,^[62] stigmasta-5, 24(28)-diene-3 β -O- α -L-rhamnoside, glucosinolates^[63] and isothiocyanate producing glucosides.^[64,65] These chemical constituents like isothiocyanate-producing glucosides isolated from various *Cleome* species were found of greater taxonomic significance because these display possible biogenesis of the glucosides [Table 1 and Figure 2].^[64,65]

Exudate flavonoids are also isolated from aerial parts of four *Cleome* species.^[66] Few structurally unique diterpene lactone constituents like (+)-Cleomeolide are isolated from *C. viscosa*.^[67] Similarly, dammarane triterpenes were isolated from *Cleome amblyocarpa*,^[68] *Cleome africana*^[59,69] and trinortriterpenoid from *Cleome chrysantha*.^[70,71] Cleomeolide a novel di terpene lactone was isolated from *C. icosandra*^[72] and *C. viscosa*^[73] while sesquiterpenes from *C. droserifolia* [Table 1 and Figure 2].^[74]

Cleome viscosa seeds contain 26% oil^[75] which is composed of major fatty acids, as methyl esters. Major oil components are palmitic acid (10.2–13.4%), stearic acid (7.2–10.2%), oleic acid (16.9–27.1%) and linoleic acid (47.0–61.1%).^[75] Plant also contains palmitoleic acid, octadec-(11E)-enoic acid, arachidic acid, eicosa-(11Z) enoic acid, linolenic acid, heneicosanoic acid, behenic acid, lignoceric acid, pentacosanoic acid, hexacosanoic acid and 12-oxo-stearic acid. Plant also contains alkanes tetracosane, pentacosane, hexacosane, heptacosane, octacosane, nonacosane, triocontane, hentriacontane and dotriacontane, as minor and trace oil constituents [Table 1 and Figure 2].^[10]

Glucocapparin and glucocleomin were isolated from *Cleome chelidonii*, *C. viscosa* *Gynandropsis gynandra*^[62] while cleosandrin from *C. icosandrica*.^[76] *C. viscosa* leaves also contain querection 3-O-(2"-acetyl)-glucoside^[53] while its roots possess lactam nonanoic acid (LNA) (2-amino-9-[4-oxoazetidin-2-yl]-nonanoic acid; C₁₂H₂₂N₂O₃, mol. wt. 242). Plant also contains various phyto-constituents such as flavonoids, alkaloids, saponins, phenols and amino acids that showed diverse biological properties.^[60,77] *C. viscosa*, *Cleome burmanni*, also contain aromatic amines, alkynes, and phenols.^[78] It also contains carotenoids, cardiac glycosides, cyanogenic glycosides, saponins, triterpenes (lupeol, epi-lupeol), sugars and tannins. *Cleome pentaphylla* seed oil contains fatty acids like oleic acid, linolic acid, palmitic acid, stearic acid, arachidic acid and some phytosterols.^[78] Plant contains glutamic acid content in higher proportion, followed by arginine, aspartic acid, lysine, tyrosine, and histidine. *C.*

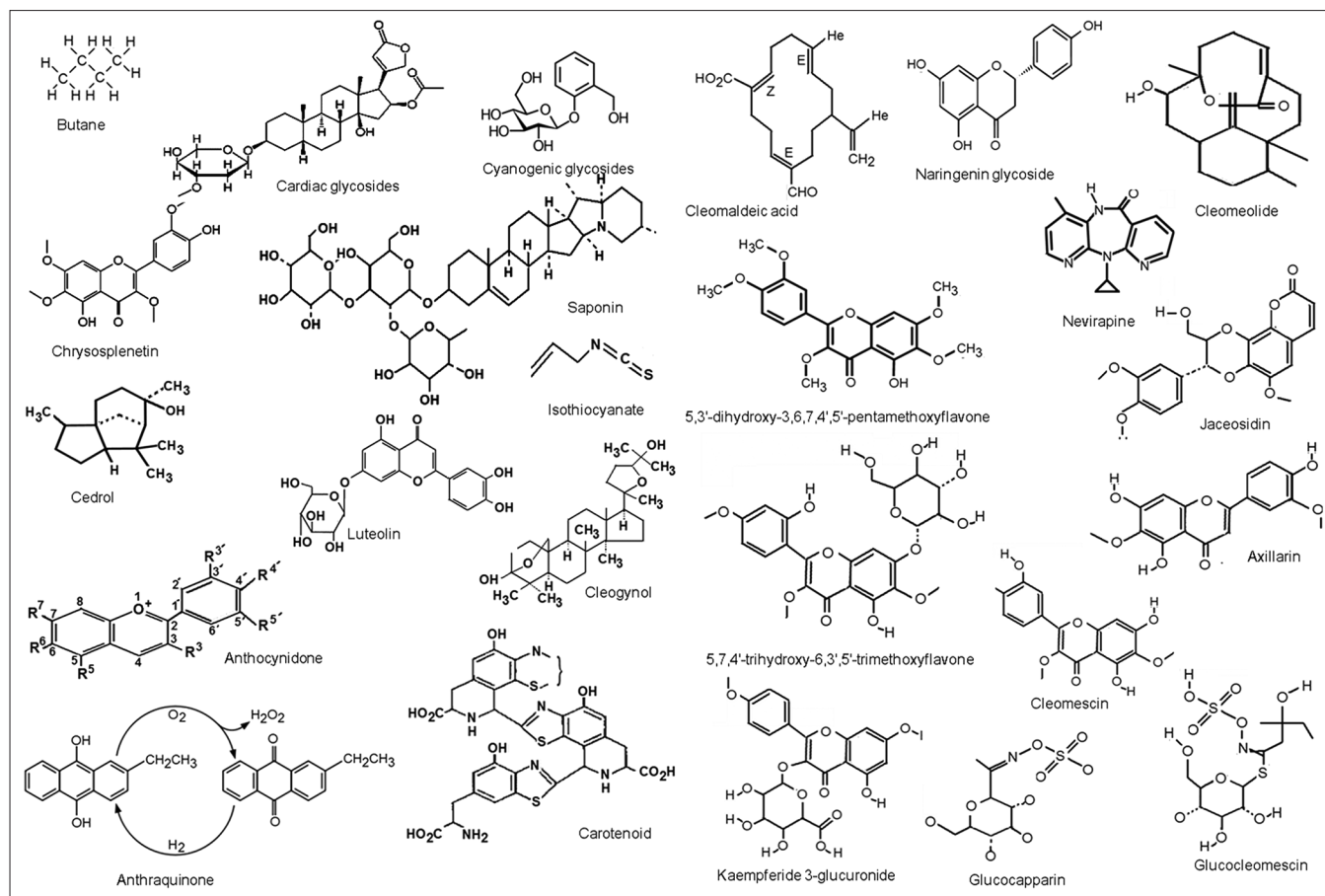


Figure 2: Major components isolated from various plant species of genus *Cleome*

gymandra contains novel compounds cleogynol (20 s, 24 s)-epoxy-19, 25-dihydroxydammarane-3-one hemiketal [Table 1 and Figure 2].

Cleome hassleriana queen line contains one monoacylated and four diacylated cyanidin 3-sophoroside-5-glucosides the main anthocyanins.^[79] Similarly, cabralealactone and ursolic acid and new triterpenoid dilactone, deacetoxybrachycarpone,^[80] cabralealactone, ursolic acid and new triterpenoid dilactone, deacetoxybrachycarpone,^[81] triterpenoid cleocarpone were isolated from *Cleome brachycarpa*^[82] and 6 dormane terpenes from *C. ambylocarpa*.^[83] Similarly, aerial parts of four *Cleome* species (*C. droserifolia*, *C. ambylocarpa*, *C. brachycarpa* and *C. chrysantha*) contain good flavonoid contents.^[67,84] Moreover, ten methylated surface flavonoids were isolated from 4 *Cleome* species that is, isokaempferide, 5,7,4'-trihydroxy-3,3'-dimethoxyflavone, jaceosidin, penduletin, axillarlin, 5,7,4'-trihydroxy-6,3',5'-trimethoxyflavone, chrysosplenetin, 5,3'-dihydroxy-3,6,7,4',5'-pentamethoxyflavone, 5,4'-dihydroxy-3,6,7,8,3'-pentamethoxyflavone and 5-hydroxy-3,6,7,3',4',5'-hexamethoxyflavone. Similarly, two triterpenes were identified in aerial parts of *C. africana*^[85] while 24 kinds of

volatile compounds have been isolated from dry seeds of *C. spinosa*.^[69] 26 bioactive components were reported in essential oil of *Cleome iberica*.^[86] while essential oil of *Cleome hirta* contains phytol, (+)-cedrol, and *n* octacosane.^[87] It shows toxic and repellent action against livestock tick and maize weevil. *C. spinosa* Jacq. dry seeds contain butane^[70] while betaine is also isolated from *Cleome* species [Table 1 and Figure 2].

Similarly, phyto-constituents like bicyclic diterpene cleomeolide were isolated from *C. viscosa* L.^[73] An optically active nevirapine, a natural analog of optically inactive nevirapine, a nonnucleoside inhibitor of HIV-1 reverse transcriptase was isolated from the seeds of *C. viscosa* by Chattopadhyay *et al.*^[57] Macrocyclic diterpene (3E, 7E, 11E)-20-oxocembra-3,7,11,15-tetraen-19-oic acid (cleomaldeic acid) were isolated from *C. viscosa* by Kosela *et al*, 1985; and Jente *et al*, 1990.^[59,88] Different *Cleome* species also contain so many biologically active phytochemicals such as triterpenes, tannins, anthraquinones, flavonoids, saponins, steroids, resins, lectins, glycosides, sugars, phenolic compounds, and alkaloids. Different diterpene derivatives are isolated from *Cleome isosandrica*^[89] and flavonoids such as kaempferol-3-O-glucoside,

rutin, kaempferol and luteolin-7-O-glucoside from *C. droserifolia* [Table 1 and Figure 2].^[90]

PHARMACEUTICAL POTENTIAL

A wide variety of phyto principles have been isolated from the *C. viscosa* plant^[14] which showed diverse biological activities such as, antibacterial, antifungal, insecticidal, nematocidal,^[2] analgesic, anti-diarrheal, anti-pyretic, hepatoprotective, antihyper lipidemic and anti-ulcer activities.^[91-94] *C. viscosa* possesses anti-inflammatory, anthelmintic, immunomodulatory, gastroprotective and free radical scavenging activity.^[14] Plant is well known for its rubifacient, vesicant and anthelmintic properties and has folklore medicinal uses.^[11] Seeds are hepatoprotective against paracetamol induced liver damage in albino rats with comparison to silymarin as standard drug. Various plant parts are used to prepare ailments external applications like to relieve rheumatism, scabies, inflammations, healing of wound and ulcers.^[95-97] *C. gynandra* is used to relieve pain, cure skin disease on leprosy, earache^[97] while *C. serrulata* is of high economic use [Table 2].^[98]

Antimicrobial Activity

The ethanol (EtOH) extracts of leaves and flowers of *C. viscosa* showed high antimicrobial activity against bacteria *Escherichia coli*, *Proteus vulgaris*, and *Pseudomonas aeruginosa*. It showed moderate activity against pathogenic fungi.^[99] Similarly, *C. gynandropsis* aqueous extract was found active against *Alkaligenes viscolactis*, *Klebsiella viscolates*, *Klebsiella aerogens*, *Bacillus cereus*, and *Streptococcus pyogens*.^[100] *C. viscosa* shows very high inhibition zone diameters against *Aeromonas hydrophilla* and *Bacillus cereus*.^[100] Similar activity is also reported in *C. droserifolia* against Gram-positive bacteria (Forssk).^[101] Flavonoid glycoside that is, quercetion 3-O-(2"-acetyl)-glucoside isolated from *C. viscosa* showed antimicrobial activity toward the Gram-positive bacteria mainly to *Staphylococcus aureus* [Table 1].^[53]

Similarly, both leaves and stems of *C. viscosa* showed anti-bacterial, anti-fungal, activity due to the presence of a 14-member ring cembranoid diterpene. It showed minimum inhibitory concentration value (μ /spot) of 5.0 μ /spot and 1.0 μ /spot against *Bacillus subtilis* (Gram-positive) and *P. fluorescens* (Gram-negative) respectively. LNA (2-amino-9-[4-oxoazetid-2-yl]-nonanoic acid; C₁₂H₂₂N₂O₃, mol. wt. 242) isolated from the root exudates of *C. viscosa* showed antimicrobial activity against bacteria that is, *E. coli*, *Pseudomonas aeruginosa* and *S. aureus* and fungi *Aspergillus fumigatus*, *Aspergillus niger* and *Aspergillus tamaraii*. Interestingly, at a dosage of 500 ppm and above, *P. aeruginosa* and *S. aureus* were totally inhibited while *E. coli* remained unaffected. On the other hand, growth of *A. niger* and *A. tamaraii* was

stimulated while there *A. fumigates* remain unaffected. This pure compound showed concentration-dependent inhibitory activity on rice, gram and mustard seeds.^[102] MECV L. showed anti-diarrheal potential in experimental animal models.^[13,103] *C. droserifolia* is autotoxic and its shoot extract inhibit seed germination and seedling growth.^[104] *C. droserifolia* shows allelopathic effects against two species of fungi *Penicillium chrysogenum* and *P. funiculosum*.^[100] Similar anti-bacterial activity is reported in *C. gynandropsis* and *C. viscosa* against *E. coli*, *P. vulgaris*, and *Enterobacter faecalis*.^[105] *C. droserifolia* (Forssk) ethanolic extracts showed anthelmintic and antibacterial activity against six bacterial strains *in vitro* cultures.^[106] Methanol extracts of *Myristica fragrans* (aril) inhibited the growth of all *Helicobacter pylori* (HP) strains with minimum inhibitory concentration *C. viscosa* (leaf).^[94] Plant possesses good chemo-preventative activities and is used in Thai traditional medicine to treat gastrointestinal ailments and inhibit the growth of HP [Table 2].

Hepatoprotective and Wound Healing Activity

Ethanolic extract of leaves of *C. viscosa* (Linn.) showed hepatoprotective activity against thioacetamide-induced^[12] and paracetamol induced hepatotoxic albino rats.^[107] It restores major liver function parameters viz. serum total bilirubin (TBL), total protein, alanine transaminase (ALT), aspartate transaminase (AST) and alkaline phosphatase (ALP) activities. Similarly, EtOH extract of the aerial parts of *C. viscosa* shows gastroprotective activity in different gastric ulcer models.^[11] *C. viscosa* also possesses free radical scavenging activity.^[11] Similarly, seeds of *C. viscosa* contain coumarinolignoids a mixture of three compounds (cleomiscosins A, B, and C) which showed significant hepatoprotective effects against CCl₄ (4)-induced hepatotoxicity in small animals mainly in albino rats.^[12] It was found well-tolerated by small animals in acute oral study. The extract was found to be effective in shortening the thiopental induced sleep in mice poisoned with CCl₄.^[12] *C. droserifolia* (Forssk.) Del., showed antidiabetic^[101] and hepatoprotective activity.^[108] Similarly, *C. viscosa* L. seed extract inhibit paracetamol-induced liver necrosis in experimental rats and restore ALT, AST, and ALP TBL biochemical parameters.^[109] Necrotic effect of paracetamol toxicity was neutralized due to the presence of flavonoid contents in plant parts.^[110,111] Seed oil of *C. viscosa* L. possesses mutagenic properties.^[26] Leaf juice of *C. viscosa* used to remove pus from wounds and seed oil from *C. gynandra* is used to cure skin diseases.^[112] Plant also shows good wound healing and hepatoprotective properties.^[113]

Anti-plasmodial Activity

Ethanolic extract of *Cleome rutidosperma* showed moderate activity against *P. falciparum* chloroquine sensitive D10strain (IC₅₀ value of 34.4 μ g/mL). This activity did

Table 2: Various therapeutic, ethnomedicinal and nutraceutical uses of *Cleome viscosa* and its associating species

Plant part	Preparation	Use
Leaves and young shoots	Vegetable mustard like flavor	Nutritive Diaphoretic, rubefacient and vesicant, juice is used in piles, lumbago and earache, and for external application to wounds and ulcers
Seeds and seed pods	Mustard substitute in curries Acids such as oleic and linoleic acids	Dietary amino acids, proteins, lipids, fatty Nutritive
Fruit and leaves	Boiled concoction	Anti-cough and anti-inflammatory ointments
Root	Extract	Antiparasitic, antimalarial, antiworm
Flower	Extract	Anti-arthritic, anticough, toxic, antimalarial
Whole plant		
Sap of leaves	Mixed with water or milk	Eye infection, rheumatism
Fresh leaves	Fresh extract	Treatment of jaundice, gastro protective Analgesic, hepatoprotective, antidiarrhoeal, anthelmintic, antiseptic, carminative, antiscorbutic, sudorific, febrifuge, cardiac stimulant, immunomodulatory, antipyretic, psychopharmacological, anti-diarrheal, anti-inflammatory, anticonvulsant and anti-diarrheal activity, antiemetic activities. antiseptic, anti leprosy
Plant leaves		Treat stomach-ache, constipation and conjunctivitis, Wound healing, prevent the sepsis. epileptic seizures Dietary constituents which are of high nutritional value
<i>Cleome viscosa</i>	Leaves and roots	
A decoction or infusion	Boiled leaves and/or roots	Facilitate childbirth in pregnant women,
Leaf	Methanolic extract	Peripheral analgesic and antiemetic activities
Leaf	Essential oil	Good repellent for mosquitoes, pesticidal, pharmaceutical
Plant	Whole plant	Fodder and vegetable
Seeds	Oil	Richness in unsaturated fatty acids, Nutritive
<i>Cleome viscosa</i>	Plant leaves	Anti-tumor, Prostate enlargement, worm infection,
<i>Cleome gynandra</i>	Plant leaves	Pruiritus, Dysentery, gonorrhoea, malaria, rheumatoid arthritis,
<i>Cleome droserifolia</i>	Plant leaves	Treatment of diabetes mellitus
<i>Cleome arabica</i> of	Plant leaves	Sedative for abdominal and rheumatic pains, fruit and leaves
<i>Cleome arabica</i> L.	Mixed with olive	Anti-inflammatory ointments
<i>Cleome dolichostyla</i>	Seed oil	Edible for human
<i>Cleome integrifolia</i>	Leaves boiled	With green corn are used in food
<i>Cleome viscosa</i>	Ethanol extracts of flowers	Active against Gram (+) and Gram (-) bacteria
<i>Cleome rutidosperma</i>	Ethanol extract	Antiparasitic <i>P. falciparum</i> CQS
<i>Cleome viscosa</i>	Solvent extracts	Nematicidal activity against <i>Meloidogyne incognita</i>
<i>Cleome viscosa</i>	Leaf extract	Anthelmintic activity
<i>Cleome burmanni</i>	Leaf extract	Anthelmintic activity
<i>Cleome viscosa</i>	Anti-diarrheal potential	Significant reduction in gastrointestinal motility in rats
<i>Cleome rutidosperma</i>	Ethanol extract	Anti-arthritic activity in Freund's adjuvant induced arthritis in male albino rats
<i>Cleome droserifolia</i>	Ethanol extract	Hypoglycemic properties
<i>Cleome viscosa</i>	Fixed oil from the seeds	Analgesic, antipyretic activity induced writhing antiemetic activity in acetic acid
<i>Cleome</i> species	Methanolic extracts of leaves	Anti-oxidant activity and free radical scavenging activity
<i>Cleome gynandra</i>	Leaves L	Lower cellular ageing stimulant of humoral immunity
<i>Cleome viscosa</i>	Chloroform extracts	Cytotoxic potential to cancerous cells, antitumor
<i>Cleome viscosa</i> S. <i>litura</i>	Solvent extracts	Larvicidal and ovicidal activity in <i>Aedes aegypti</i> <i>Callosobruchus chinensis</i>
<i>Cleome gynandra</i>	Cidal	Red spider mite (<i>Tetranychus urticae</i> Koch)
<i>Cleome viscosa</i> beetle	Essential oils	Insecticidal, oviposition inhibitory and repellent activity against pulse
<i>Cleome hirta</i>	Cidal	Livestock tick, and maize weevil
<i>Cleome arabica</i>	Solvent extracts	Antifeedant to Cotton Leafworm, <i>Spodoptera littoralis</i> larvae
Whole plant	Digested biomass	Manure

not found in aqueous extract.^[114] Similarly, the diethyl ether fraction was found to be the most potent fraction and showed good antiplasmodial activity (IC50 value

of 8.1 µg/mL). However, certain phyto-constituents like terpenoids or flavonoids have been found to be responsible for anti-malarial activity.^[115]

Nematicidal Activity

Cleome viscosa solvent extracts also had high nematicidal activity against plant parasitic nematode *Meloidogyne incognita* Chitwood.^[2] Similar nematicidal activities was observed against root-knot nematode *Meloidogyne javanica*.^[116]

Anthelmintic Activity

Flavonoid glycoside *C. viscosa*^[117] and *C. burmanni* exhibited significant anthelmintic activity.^[118] Similar anthelmintic, antipyretic and tonic properties are also reported in *C. serrulata*.^[119] The crude alcohol and aqueous extracts of the seeds of *C. viscosa* Linn. showed anthelmintic activity against *Pheretima posthuma* and *Ascaridia galli* at a concentration ranging from 10 to 100 mg/mL.^[120] Both extracts exhibited considerable anthelmintic activity in a dose-dependent manner. The most significant activity was observed at the highest concentration of 100 mg/mL against both types of worms.^[120] Methanol, aqueous and chloroform extracts of *C. viscosa* and *C. burmanni* showed the anthelmintic potential against the Indian earthworm *P. posthuma*. MECV at a concentration of 2000 µg/ml was detected to be the most effective treatment dose due to the presence of terpenoids.^[117]

Anti-diarrheal Activity

Methanol extract of *C. viscosa* L. (Family; *Capparidaceae*) showed anti-diarrheal potential in experimental rats. It also showed significant inhibitory activity against castor-oil-induced diarrhea and PGE2 induced enteropooling in rats.^[13] MECV causes a significant reduction in gastrointestinal motility in the charcoal meal test in rats. *C. viscosa* is an anti-diarrheal agent.^[13]

Anti-arthritis Activity

The ethanolic extract of *C. rutidosperma* shows anti-arthritis activity in Freund's adjuvant induced arthritis in male albino rats. The dose regimens of 200 mg/kg body weight (BW) of the ethanolic extract of *C. rutidosperma*, did 44.0% inhibition in arthritis induced rat model in comparison to the standard drug prednisolone (5 mg/kg).^[121] Similar, diuretic and laxative activity is reported in EtOH extract and its fractions of *C. rutidosperma* aerial parts.^[122]

ANTIDIABETIC

Cleome droserifolia contains hypoglycemic properties as it significantly suppressed the rise in peripheral blood glucose concentrations in albino rats.^[123] Its ethanolic leaf extract shows hypoglycemic effects in experimentally induced diabetes in animal models, and on nonenzymatic anti-oxidant, glycogen, thyroid hormone and insulin levels. The methanol extract of *C. droserifolia* contains two flavonoids as active components.^[124] Furthermore, administration of crude plant extract of *C. droserifolia* significantly decreases glucose levels and proves some

biochemical parameters in alloxanized rats (110 mg/kg). *C. droserifolia* significantly increased glycogen content by 48.2% as compared to diabetic group.^[125] Serum albumin alpha globulin and beta globulin concentrations were significantly decreased (by 30.7%, 30.9% and 70.3%, respectively) in diabetic group ($P < 0.001$) as compared to control mice. Insulin was significantly decreased ($P < 0.0001$) in diabetic mice and increased upon treatment with *C. droserifolia* ($P < 0.01$).^[126] Ethanolic extract not only exhibited anti-hyperglycemic properties but also reduced oxidative stress in alloxan-induced diabetic mice while enhancing insulin release. Similarly, petroleum ether and benzene extracts of *Cleome felina* showed anti-diabetic and anti-hyperlipidemic activity in alloxan diabetic rats.^[127] Similar hypoglycemic activity was reported in *C. droserifolia* (Forsk).^[128]

METHANOL EXTRACT OF CLEOME VISCOSA (CVME)

Antipyretic Property

Methanol extract of *C. viscosa* Linn. showed antipyretic activity at dose regimens ranging from 200 to 400 mg/kg BW p.o. It caused a significant reduction in normal body temperature and yeast-provoked elevated temperature in a dose-dependent manner in albino rats.^[13] The anti-pyretic effect of CVME was found to be more effective in comparison to paracetamol (150 mg/kg p.o.) a standard anti-pyretic agent.^[13,129]

Analgesic and Antiemetic Activity

Fixed oil from the seeds of *C. viscosa* showed analgesic and antiemetic activity in acetic acid induced writhing mice (intraperitoneally) and chick emetic model (oral treatment) respectively.^[130] *C. viscosa* aqueous and alcoholic extracts of seeds showed analgesic activity^[24] in acetic acid-induced mice.^[27] Similarly, *C. rutidosperma* showed analgesic, anti-inflammatory and antipyretic activity in ethanolic extracts.^[131]

Anti-inflammatory Activity

The flavonoid glycoside isolated from *C. viscosa* showed significant anti-inflammatory activity on carrageenan-induced rat paw edema (*in vivo*). This anti-inflammatory effect of the flavonoid glycoside may be due to the inhibition of prostaglandin synthesis.^[53] Similarly, quercetin 3-O-(2"-acetyl)-glucoside obtained from ethyl acetate (EA) fraction of *C. viscosa* showed anti-inflammatory activity against carrageenan-induced rat paw edema (*in vivo*). Oral administration of coumarinolignoids inhibited the pro-inflammatory mediators and enhances the production of anti-inflammatory mediator in dose dependent manner.^[132] Similarly, coumarinolignoids isolated from the seeds of *C. viscosa* consist of a racemic mixture of cleomiscosins A, B and C which showed strong anti-inflammatory activity.^[133] The expression of

oviposition inhibitory and repellent activity against pulse beetle against stored grain insect pests.^[155] Similarly, essential oil from *C. hirta* possesses phytoconstituents such as phytol, (+)-cedrol, and n-octacosane that were found cicidal to livestock tick, and maize weevil.^[156] Similarly, crude extract of *Cleome* were found highly toxic to egg-masses of *M. javanica* root-knot nematode.^[116] *C. arabica* extracts affect feeding and survival of cotton leafworm, *Spodoptera littoralis* larvae.^[157] Extracts from seeds of *C. viscosa* showed larvicidal potential against 3rd or early 4th stage larvae of *Anopheles stephensi* (liston), *A. aegypti* (linnaeus) and *Culex quinquefasciatus* (Say) in different organic solvents.^[158] *C. viscosa* shows high insecticidal activity against third instar larvae of *A. aegypti* as the LC50 values were reported 126.12, 82.43, 179.26 and 123.34 ppm, respectively. These extracts have shown most significant ovicidal activity as 100% egg mortality (zero hatchability) was observed at 300 ppm and 420 ppm for *C. viscosa*.^[159]

CONCLUSION

Cleome viscosa L. (*Cleomaceae*) is an important terrestrial, annual, sticky herb of a very low height, which is also used as fodder. It is an important traditional medicine of the Indian-Ayurvedic and Chinese-medicine system documented for rheumatic arthritis, hypertension, malaria, neurasthenia, and wound healing.^[160] *C. viscosa* L. (*Capparidaceae*) is used traditionally in the Indian system of medicine as a carminative, anthelmintic, and diuretic, and used for healing wounds, ulcers and diarrhea. Traditionally, this plant is used in various disorders such as diarrhea, fever, inflammation, liver diseases, bronchitis, skin diseases and malarial fever. The leaves are diaphoretic, rubefacient and vesicant and its juice is used in piles, lumbago and earache and for external application to wounds and ulcers. Leaves, seeds, and roots are widely used in traditional and folkloric systems of medicine for the treatment of various ailments by the local people. Its various aerial parts are used to treat respiratory tract infections and wounds. *C. viscosa* is used for used for Osteoarthritis of knee in Thai medicine.^[161] Ethanolic extract of *C. viscosa* shows neuroprotective effect against streptozotocin induced diabetic neuropathy in Wistar rats.^[162] Topical application of *C. viscosa* increases the expression of basic fibroblast growth factor and type III collagen in rat cutaneous wound.^[160]

Plant bear long slender pods containing seeds that are oil producing. The oil is very similar in fatty acid composition to the nonedible oils of rubber, jatropha, and pongamia, soybean, safflower, linseed and rapeseed edible oils. Oil shows richness of unsaturated fatty acids. The *C. viscosa* biodiesel head the properties of standard biodiesel specified by ASTM and Indian Standards Bureau except it had low oxidation stability. Fatty oils of the seeds of *C. viscosa* contain 5 important fatty acids palmitic acid (10.2–13.4%), stearic acid (7.2–10.2%),

oleic acid (16.9–27.1%) and linoleic acid (47.0–61.1%). In addition, palmitoleic acid, octadec-(11E)-enoic acid, arachidic acid, eicosa-(11Z)-enoic acid, linolenic acid, heneicosanoic acid, behenic acid, lignoceric acid, pentacosanoic acid, hexacosanoic acid, 12-oxo-stearic acid, and the alkanes tetracosane, pentacosane, hexacosane, heptacosane, octacosane, nonacosane, tricontane, hentriacontane and dotriacontane. Fresh leaves of *C. viscosa* are used as vegetable while seeds are used in curries.

Both leaf and seed oil is used for various veterinary and medicinal purposes while whole plant is used to cure rheumatism. Leaves are used very effectively for the treatment of jaundice and its decoction is used for eyesore. The juice of the leaves has been used to relieve earache. The leaves are diaphoretic, rubefacient and vesicant used as an external application to wounds and ulcers. The sap of leaves mixed with water or milk is applied to the eye in Java. The seeds contain 18.3% oil, a mixture of amino acids, fatty acids and sucrose. The whole herb is rubbed on the body against rheumatism. *C. viscosa* L. is used traditionally in the Indian system of medicine as a carminative, anthelmintic and diuretic and are used for wound healing, ulcers and diarrhea. Fresh leaves of this plant are used very effectively for the treatment of jaundice in the folk medicines in India. In addition *C. viscosa* possesses significant hepato and gastroprotective and free radical scavenging activity. The leaves, seeds and roots of the plant are widely used in traditional and folklore systems of medicine and displayed beneficial curative effects as anthelmintic, antiseptic, carminative, antiscorbutic, sudorific, febrifuge, cardiac stimulant, immunomodulatory, antipyretic, psychopharmacological, anti-diarrheal, and hepatoprotective, anticonvulsant, anti-diarrheal. Plant possesses diverse biological activities, antibacterial, antifungal, insecticidal and nematicidal. The topical application of CVME (2.5% w/w) significantly accelerated the wound contraction rate (95.14%, 24 postoperative days), increased the hydroxyproline content (3.947 mg/100 mg tissue), and improved histopathology of wound tissue as compared to control groups. Western blot analysis revealed that CVME significantly upregulated the expression of COL3A1 and bFGF and increased the smad-mediated collagen production in granulation tissue.^[160] The plant is said to be used by the poorer classes as vegetable. Its leaves and young shoots are used to cook like a vegetable, which is having sharp mustard-like flavor. The pungent seeds and seed pods are used as a mustard substitute in curries. Its extracts were found active against *B. subtilis*, *P. fluorescens*, *Cyclus formicarius elyangulus* (summer, coleopteran, curculionidae), and parasitic nematode *M. incognita*. Plant seeds can be used for obtaining edible oil, essential oils and domestic fuel oil if plant is cultivated in large area. Plant can become a source of energy supply to the local people, but it needs technological development to

harvest all economic ingredients of this plant for domestic use. Plant can be grown in hot desert climate at low rainfall, and its new economic cultivars can be grown to generate new alternates of fodder crops in dry land areas. Digested biomass with oil cake and cow dung is used as manure in the crop that enhances the yield as well as reduces infestation of termites and hopes due to systemic and volatile activity. Plant essential oil work as a good repellent for mosquitoes and this plant can be used as a good source of pesticides and pharmaceuticals.

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